PUBLIC LIBRARY
JUL 16 1952
ST LOUIS

TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909

INCORPORATED 1930

CONTENTS

Page

Specification and Testing of Fluorescent Lighting Fittings and Components, by G. Fahey, B.Sc., D.F.H. (Hons.), *(Member)*, D. T. Waigh, B.Sc., A.Inst.P., *(Member)*, and W. R. Bloxsidge, A.M.I.E.E., *(Member)* - - - - 131

Additions to List of Members - - 156

Fellowship - - - - - - 156

Annual General Meeting - - - 157

VOLUME XVII
No. 6 — 1952

32 VICTORIA ST
LONDON, SW1

Annual Subscription to Non-Members - £2.2.0
Price per Number to Non-Members - 5s. 0d.

The I.E.S Council and Committees

Session 1951-1952

Council

President :—J. G. HOLMES, B.Sc. (*Fellow*).

Vice-Presidents :— W. J. WELLWOOD FERGUSON, M.B., Ch.B., A. G. HIGGINS, M.Sc. (*Fellow*), E. C. LENNOX (*Fellow*), L. C. RETTIG (*Fellow*), W. S. STILES, O.B.E., D.Sc. (*Fellow*).

Members of Council :—

Elected Members:—

S. ANDERSON, G. G. BAINES, S. S. BEGGS, N. BOYDELL, H. G. CAMPBELL, W. E. HARPER, P. HARTILL, R. G. HOPKINSON, C. A. HOSKINS, A. W. JERVIS, T. S. JONES, J. S. MCCULLOCH, L. H. MCDERMOTT, A. R. MCGIBBON, A. M. OLSON, A. H. OWEN, A. G. PENNY, C. W. M. PHILLIPS, E. B. SAWYER, J. F. STANLEY, D. A. STRACHAN, W. J. P. WATSON, W. D. WRIGHT.

Ex-Officio Representatives of Centres:—

R. G. CAPELL (*Bath and Bristol*), R. A. LOVELL (*Birmingham*), N. D. HOUSTON (*Cardiff*), C. K. ROSS (*Edinburgh*), A. B. WRIGHT (*Glasgow*), H. E. PHILLIPS (*Gloucester and Cheltenham*), J. SEWELL (*Leeds*), W. N. COULSON (*Leicester*), D. ST. C. BARRIE (*Liverpool*), J. MARTIN (*Manchester*), W. H. DODGSON (*Newcastle*), C. S. CAUNT (*Nottingham*), G. L. TOMLINSON (*Sheffield*).

Hon. Treasurer :— W. J. JONES.

Hon. Secretary :— H. C. WESTON.

Hon. Editor of Transactions :— W. E. HARPER

All Past-Presidents of the Society are *ex-officio* Members of Council.

Committees

GENERAL PURPOSES COMMITTEE: J. G. Holmes (*President*), W. J. Wellwood Ferguson, A. G. Higgins, E. C. Lennox, L. C. Rettig, W. S. Stiles (*Vice-Presidents*), L. J. Davies (*Past-President*), W. J. Jones (*Hon. Treasurer*), H. C. Weston (*Hon. Secretary*), G. L. Tomlinson (*Sheffield Centre*), N. D. Houston (*Cardiff Centre*).

PAPERS COMMITTEE: S. Anderson, H. G. Campbell, W. E. Harper, R. G. Hopkinson, T. S. Jones, W. S. Stiles, D. A. Strachan, J. M. Waldram.

EDUCATION COMMITTEE: R. O. Ackerley, G. G. Baines, S. S. Beggs, A. Cunnington, A. G. Higgins, J. T. MacGregor-Morris, C. W. M. Phillips, J. W. T. Walsh.

I.E.S. CODE COMMITTEE: R. O. Ackerley, R. G. Hopkinson, E. B. Sawyer, F. C. Smith, W. S. Stiles, H. C. Weston.

CENTRES JOINT COMMITTEE: One representative from each Centre. Council's Representatives: E. C. Lennox, A. G. Penny, E. B. Sawyer.

(The President, Hon. Secretary and Hon. Treasurer are *ex-officio* members of all committees.)

Secretary :— G. F. COLE, 32, Victoria-street, London, S.W.1.

Specification and Testing of Fluorescent Lighting Fittings and Components

By G. FAHEY, B.Sc., D.F.H. (Hons.), *(Member)*, D. T. WAIGH, B.Sc., A.Inst.P., *(Member)*, and W. R. BLOXSIDGE, A.M.I.E.E., *(Member)*.*

Summary

A specification for equipment ensures a certain performance. Its preparation requires a knowledge of the equipment and the factors which affect its performance. These problems are discussed for the mains voltage fluorescent lamp, control gear and fitting, and methods of test are described.

It is suggested that tests should be made both in "free air" and "in fitting," and that limiting conditions for satisfactory operation of lamps, control gear and fitting should be specified for both circumstances, assuming that control gear and fitting are designed to lamp requirements.

A term to denote the "complete lighting unit" is recommended.

(1) Introduction

This paper is not intended to be a complete specification for fluorescent lamps and their equipment, or to provide all the data for preparation of a specification. It is hoped that it will serve as a basis for discussion both of the individual characteristics of lamp, control gear and fitting for specification purposes, and of the inter-related effects when these components are combined to form the complete lighting unit—the luminaire. Such discussion would help in preparing specifications and in ensuring satisfactory operating conditions. Little or no reference is made to physical dimensions, except where they may have a bearing on the behaviour or satisfactory operation of the equipment. The paper is limited to interior lighting equipment.

(2) Lamp Specification and Testing

(2.1) Factors Affecting Performance

The lamp has five important characteristics by which it may be graded or specified. They are affected by variable factors as indicated in Table 1. It is necessary to examine their relationship, and by specification to eliminate for purposes of test as many variables as possible.

In circuits where the peak voltage produced is lower than the minimum necessary to strike the lamp in use, the lamp will not strike unless it is assisted. Effective assistance is given by an earthed conductor adjacent to, or touching, the surface of the lamp; this conductor increases the potential gradient in the gas, thereby increasing ionisation and reducing lamp striking volts. Differences up to 50 in striking volts may be found between the same lamp with and without an adjacent earthed conductor. It is, therefore, necessary for test purposes that the dimensions of the earthed surface and its distance from the lamp should be specified.

Circuits requiring an adjacent earthed conductor are those with transformer start (even when a pulse is produced by means of the P.F. correction capacitor on closure of the main switch), and those with certain types of glow switch.

In such circuits it is found that lamp striking volts are affected by the lamp surface resistance(1), which may be lowered by the presence of moisture films formed when the atmospheric relative humidity exceeds 60 per cent. The striking voltage increases to a maximum as the lamp surface resistance increases from one megohm

* The authors are with Thorn Electrical Industries, Ltd., London. The manuscript of this paper was first received on November 21, 1951, and in revised form on January 16, 1952. The paper was presented at a meeting of the Society held in London on February 12, 1952.

Table 1
Factors Affecting Lamp Performance

External variable factor	Lamp characteristics affected by external variable factors				
	Striking Volts	Running V.A.W.	Efficiency	Colour	Life
Adjacent earth	Yes	No	No	No	No
Humidity	Yes	No	No	No	No
Number of starts	No	No	No	No	Yes
Ambient temperature	Yes	Yes	Yes	Yes	Yes
Starter transformer	Yes	Yes	No	No	Yes
Starter switch	Yes	No	No	No	Yes
Ballast	Yes	Yes	Yes	Yes	Yes

[For the sake of simplicity, where the effect is very slight, the answer is given as No].

to about 100 megohms, and then decreases as the resistance rises further to about 1,000 megohms.

The effect of the moisture film is to reduce the potential gradient in the gas, and thus to destroy the usefulness of the adjacent earthed surface. To counteract this effect, lamps should be coated with a water-repellent substance or the lamp surface should have a conductor of resistance not more than one megohm in contact with it along its whole length.

Fig. 1 shows the effect of relative humidity on lamp striking volts. Above 95 per

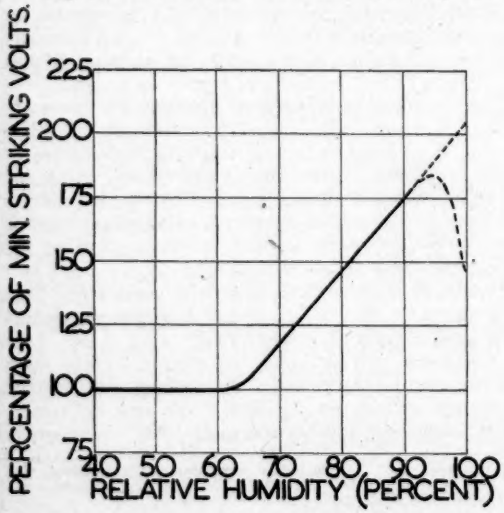

Fig. 1. Relation between striking volts and humidity.

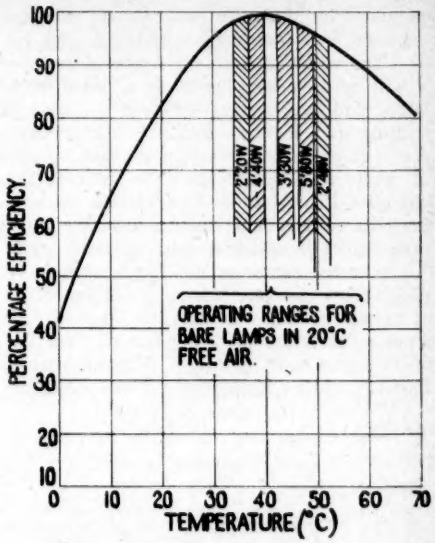

Fig. 2. Relation between lamp efficiency (lm./w.) and temperature of glass wall at top centre of lamp.

cent. R.H. the striking volts may fall if there is a deposit of soluble matter on the lamp surface, which lowers the surface resistance below that giving maximum striking volts. The striking voltage then depends on the period of exposure to high humidity.

A factor which affects all lamp characteristics is ambient temperature, and it is therefore desirable that all lamps should be tested at a temperature within a specified

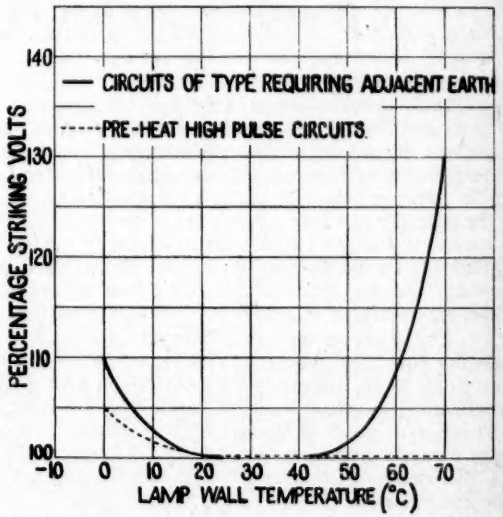

Fig. 3. Effect of lamp wall temperature on striking voltage.

range. For moderate accuracy the range 18-25 deg. C. is suggested; if precision is required tests should be made at 20 deg. C. $\pm$ 1 deg. C.

The effect of ambient temperature on efficiency is shown in Fig. 2, from which it will be seen that the effect depends on the designed operating temperature of the lamp, and is therefore different for each lamp size. The effect of temperature on striking volts is shown in Fig. 3, and is most noticeable in circuits requiring an adjacent earth. Colour is altered by changes in mercury vapour pressure caused by variation in lamp wall temperature; in general the warmer the colour the greater is the change. Fig. 4 shows the relation between ambient temperature and lamp running current, voltage and watts. Running current is seriously affected, and this in turn may reduce lamp life at high ambient temperatures.

Another factor which has a serious effect on lamp life, although little on any other lamp characteristic, is the frequency of switching on and off, i.e., the number of times the lamp is started. The reduction of the running period between starts from three hours to one hour may reduce life by 50 per cent. The extent of this effect varies with lamps of different manufacture, and it is therefore desirable that there should be agreement on the switching cycle since much extra testing would be

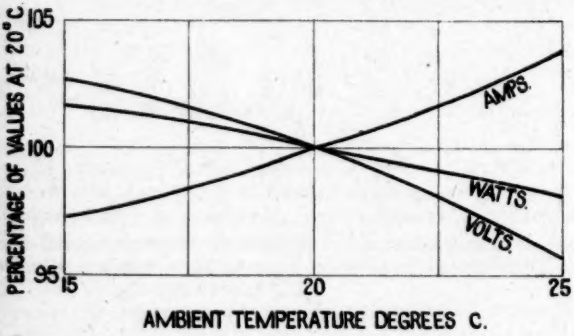

Fig. 4. Relation between ambient temperature and running characteristics of 5 ft. 80w. lamp.

needed to establish the relation between the effect of different cycles for different makes of lamps.(2)

Both the life and striking volts of a lamp are considerably influenced by the characteristics of the starting device, whether transformer or switch. Inadequate cathode pre-heating, caused either by too low transformer voltages or by too short pre-heat time of a starter switch, will result in increased starting voltage and a reduction in life. The reduction in life is particularly severe if, with inadequate cathode heating, the difficulty in starting is overcome by increasing the voltage applied across the lamp. Lamps should be tested with the type of starter (i.e. switch or transformer) to be used. It should be possible to ensure reproducible results by specifying the type of switch and the authors have found that a thermal switch is suitable, provided that the pre-heat time is specified within the close limits of 1.0-1.5 seconds.

The choke is the most important factor of all in determining the performance of the lamp, and when used for testing lamps should be specified within close limits. In order to do this the first requirement would be an "ideal" lamp with accurate and permanent characteristics. A single "ideal" lamp is impracticable, but it is possible to select a group of good lamps, excluding "outsiders," which together provide all the characteristics of an ideal lamp. An approximate parallel to this conception is the C.I.E. Standard Observer which is derived from a number of observers with "normal" colour vision.

Having acquired such a group of lamps a "standard" choke can be made so

Table 2

Conditions of Test for Lamp Striking Volts

	Starter switch	Starter transformer
Ambient temperature	18–25 deg. C.	18–25 deg. C.
Choke	Reference choke	Reference choke
Adjacent earth	None	Flat metal strip 1½ in. wide, length of lamp, ½ in. from lamp surface.
Humidity	Any	95 per cent. R.H.
Starter	Thermal type, pre-heat time 1–1.5 seconds.	Transformer with characteristics in middle of specification.
Max. time allowed for lamp to start.	Determined by switch, not lamp.	2 seconds.
Test voltage.	90 per cent. of lowest nominal supply voltage on which lamp is required to function.	As starter switch.

that, at rated voltage, the average watts consumed by the lamps in the group are the rated value. The choke should be specially constructed and have much closer tolerances in watts' loss and linearity of characteristics, than production chokes. On the basis of figures obtained with the "ideal" lamp and "standard" choke, limits can now be set for production choke performance in terms of choke characteristic and lamp operating conditions. The performance of the production chokes is partly determined by cost and will be somewhat lower than that of the "standard" choke. A "reference" choke for use in tests, may be defined as a production choke whose performance lies at the middle of the appropriate specification.

An important ballast characteristic, not usually specified, is "peak or crest factor."* Lamps run with ballasts having a crest factor of 2.0 may have only half the life of lamps run with ballasts of crest factor 1.45(3).

(2.2.) Specification and Methods of Test

It is necessary to set out methods which may be used for testing lamp characteristics and to suggest tolerances and pass limits.

(2.2.1) *Lamp Striking Volts and Running Characteristics.*

Striking volt tests should be made with unused lamps, as an improvement in performance may occur after a period of running. The pass limit suggested is commonly accepted, and is a compromise between the need for an adequate margin of safety and the practical amount by which the striking volts can be lowered without affecting other lamp characteristics.

Conditions of test and suggested pass limits for lamp striking volts and running characteristics are given in Tables 2 and 3.

* Peak or crest factor = Ratio of peak lamp current to R.M.S. lamp current.

(2.2.2) *Lamp Efficiency*

It is intended to refer only briefly to those factors which affect lamp efficiency and the accuracy of its measurement.[4] Measurements should be made either with the lamps operating in a draught-free enclosure whose temperature can be maintained constant at 20 deg. C., or at some other temperature which is the same for both test lamps and standards. If neither alternative is possible and measurements on the standards and test lamps have to be made at different temperatures, the results must be corrected for the temperature difference. Ballasts should have a low crest factor, preferably not more than 1.6. Lamps to serve as photometric standards are usually calibrated at the National Physical Laboratory and are selected from groups of lamps submitted. Such groups should consist of at least three lamps of the same size, wattage and spectral distribution as those to be measured. They should be run-in for 500-1,000 hours, depending on the type of lamp, until the rate of change of efficiency is sufficiently low. These standards, with a stated accuracy of $\pm$ 3 per cent. on individual measurements, should be used to calibrate sub-standard lamps, some of which may be used as working standards. The latter may be used regularly and checked against the sub-standards monthly. All these lamps should be checked against the standards yearly, or when necessary. At the time of measurement the only instrument in circuit should be a wattmeter of negligible power consumption. A manual starter should be used and each lamp cathode should be short-circuited after the lamp has struck. When repeat measurements are made on a lamp, the positioning of the pins with reference to the circuit should be the same as in the original measurements.

Complete photometric integration is not necessary if measurements are made by

Table 3

Conditions of Test for Lamp Running Volts, Amps and Watts

Ambient temperature	Preferably 20 deg. C. $\pm$ 1 deg. C. after stable conditions have been reached in free air without draughts.
Starter	Manual type preferred.
Choke	Reference choke.
Instrument types	Only those substantially unaffected by wave form, e.g. moving iron, dynamometer or electrostatic.
Instrument resistances	Total resistance in series not more than 3 ohms. Total resistance in parallel not less than 10,000 ohms.
Test Voltage	Set to middle of range covered by choke tapping.
Pass limits— Watts	$\pm$ 3 per cent. for batch averages.
Volts	+ 5 per cent. for batch average; no lower limit needed. Not more than 10 per cent. of lamps should have voltages more than 10 per cent. above batch average.
Amps	+ 5 per cent. for batch average; no lower limit required.

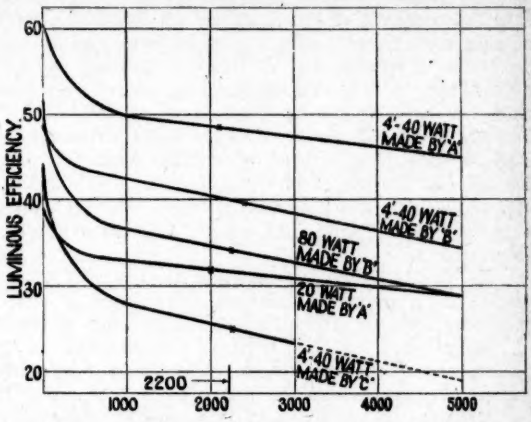

Fig. 5. Lamp efficiency maintenance throughout life.

straight substitution. A large sphere is an advantage, but with care good results can be obtained using a rectangular box 6 ft. x 2 ft. x 2 ft. The photometer paint is not important when the spectral distribution of standards and test lamps is similar, but where correction factors relating each colour to the standards are used the colour retention of the paint must be good. By using a linear photocell and the best available correcting filter, agreement with N.P.L. standards to within $\pm$ 2 per cent. on batch averages is possible.

It is useful to specify limits for (a) the average efficiency of the batch at 100 hours, (b) the average efficiency throughout the specified life (i.e., throughout the first "n" thousand hours), and (c) the spread within the batch. Batch averages may be specified at not more than 5 per cent. below the figure declared by the manufacturer.

The "average through life figure" appears to present a difficulty in view of the already long lives of fluorescent lamps and the possibility of still further increases. The similarity in shape of lumen maintenance curves (Fig. 5) irrespective of lamp size, colour or manufacturer, reduces the problem to one of ascertaining the point at which the average value is reached. The error introduced by taking a fixed point for all lamps with the same nominal life (e.g., "average point" of 2,200 hours for lamps with nominal life of 5,000 hours) will not be more than one lumen per watt. With lives of at least 5,000 hours, life tests, even to the average point, take four months or more. It is unlikely that satisfactory accelerated life tests will ever be devised. It seems evident, therefore, that fluorescent lamps will be accepted or rejected by customers on the basis of the 100-hour figures and the customers' experience of the performance of lamps in service.

Limitation of spread within a batch can best be achieved by limiting the low efficiency lamps, since variation upwards is not harmful.

(2.2.3) *Colour*

It is not proposed to consider in detail the measurement of colour ([5]), which is generally expressed in terms of C.I.E. co-ordinates. It is, however, of value to state some outstanding problems related to colour and colour rendering.

One point which warrants further consideration is whether it is desirable to limit the number of colours in which lamps are made, but there is no doubt that the main colours should at some time be specified and named. Names should not be borrowed for colours which do not comply with the specification.

It is also useful to consider whether it is possible to relate the limits defined by

C.I.E. co-ordinates to colour differences discernible by the user. With the low brightness large area source of a fluorescent lamp and fitting, colour differences measurable only with instruments of the highest accuracy can readily be seen by users. It is unreasonable to expect such accuracy of colour control that there is no observable difference between lamps of the same nominal colour made by different makers at different times, but such uniformity is not unreasonable for lamps of the same batch made by one manufacturer. Somewhat wider tolerances are to be expected between the different batches of one manufacturer's production, though experience has shown that these tolerances need not be large. Further work is necessary before an acceptable agreement relating the colour differences observed to those measured can be formulated.

To specify the colour-rendering properties of a lamp requires the definition of its spectral distribution of luminance, the relation of this definition to some standard of excellence, and the setting of permissible limits of departure from this standard.

Much work has been done on the definition of spectral distribution(6), and it is generally agreed that the spectral band system is an essential approximation. No finality has yet been reached on the actual bands to be used(7).

Relating this definition to an acceptable standard presents more difficulty. Judd and Jerome(8) have suggested that the standard should be the black body radiator nearest in colour to the lamp in question, but this standard is unsatisfactory for colours well off the black body locus. It would also be undesirable for existing fluorescent lamps to be taken as standard, since this would merely force conformity with existing phosphors. Even if suitable standards could be decided at this stage, specification of permissible limits for each band would depend on a subjective assessment of the effect of the several combinations of tolerances.

The difficulties in the way of a specification for colour-rendering are thus self-evident.

(2.2.4) *Lamp Life*

Lamps for life test should be run on ordinary circuits using production ballasts with crest factors of not more than 1.8, and starters of the types normally used. Test racks will usually contain a large number of lamps close together, and should be so constructed that overheating of the lamps is avoided. Overheating may cause the lamps to take an excessive current which will result in short life and poor lumen maintenance. If necessary forced ventilation should be used.

Automatic mains switches giving an on-period of three hours and an off-period of half an hour are desirable, and this cycle may be regarded as standard. Longer on-periods result in longer lives and vice versa.

Failures may be classed under three main headings:

(i) "Initial" failures, occurring during the first 100 hours and caused by

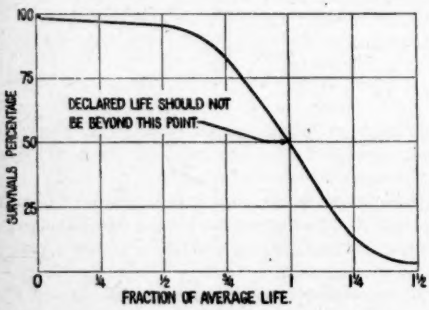

Fig. 6. Typical form of mortality curve of fluorescent lamps on three-hour switching cycle.

Table 4

Probability of Batch Acceptance of Lamps under various Sampling and Test Conditions

Actual percentage defective in bulk	Specified pass limits	Chance of passing bulk (for numbers in test group as under)					
		5	5+5	10	10+10	20	20+20
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
5	Pass outright if 0 failures.	77	—	59	—	35	—
10	Reject outright if 1 or more.	59	—	35	—	12	—
20		33	—	11	—	1	—
5	Pass outright if no failure.	—	95	—	78	—	48
10	Select 2nd group if 1 failure.	—	78	—	48	—	15
20	No failures permitted in 2nd group.	—	46	—	23	—	1
5	Pass outright if 0 or 1 failure.	97	—	90	—	73	—
10	Reject outright if 2 or more failures.	92	—	74	—	38	—
20		74	—	38	—	2	—
5	Pass outright if 0 or 1 failure.	—	99	—	96	—	87
10	Select 2nd group if 2 failures.	—	98	—	88	—	49
20	Pass if 0 or 1 failure in 2nd group.	—	89	—	49	—	7

manufacturing faults, some of which may not show until the 100 hour test. Initial failures should not exceed 2 per cent.

(ii) "Premature" failures, occurring during the first half of the declared life, and which should not exceed 5 per cent.

(iii) "Normal" failures, occurring at intervals thereafter; total failures should not exceed 50 per cent. at the declared life point.

A typical mortality curve for a group of fluorescent lamps is shown in Fig. 6, and can only be obtained with accuracy by testing a large number of lamps; the number should be of the order of 100.

In practice if smaller numbers are taken, concessions on the number of failures are necessary. Table 4 shows the probability of passing or rejecting 5, 10 or 20 per cent. defective lamps (i.e., failures before half declared life) for varying numbers of lamps in the test group.

(3) Control Gear Specification and Testing

The normal A.C. control gear for a fluorescent lamp circuit comprises choke, capacitor and starting device. Basically its functions are to provide sufficient voltage for proper starting of the lamp, to supply correct preheat current for proper starting of the lamp in a preheat type circuit, and to supply the rated operating current and power to the lamp.

To ensure satisfactory performance, however, these components should possess additional features. They should absorb as little power as possible, have no adverse effect on the lamp life or maintenance, be reasonably quiet in operation, be safe electrically and mechanically, and have a long life. It is necessary to consider each component separately, and to set limits which will provide a basis for tests.

(3.1) Choke

The electrical characteristics of the choke have been determined by considering an "ideal" lamp run by a "Standard" ballast. Type tests are carried out on production chokes to ascertain whether these characteristics have been provided within the stated limits.

The use of the "ideal" lamp is laborious and introduces an additional variable so that, with one exception, it is undesirable to test the electrical characteristics of the choke and its performance by a method which requires a lamp in the circuit. Tests with a lamp in circuit, however, are of value when dealing with the circuit as a whole. (Section 5).

It is necessary to limit the temperatures on choke container and coil, but the setting of one limit for all types of choke may restrict unduly the choice of materials. There is a limiting operating temperature for each design of choke. For the compound filled type this limit may be determined by the flow temperature of the compound and the construction of the container. For air-cooled varnish impregnated types, the melting point of solder used for internal connections may set the limit. If there are no soldered connections then the properties of the impregnating varnish may be the deciding factor. The limit for the latter is much higher than the limit for the compound-filled chokes.

It is felt that chokes should be "temperature graded." The manufacturer should state the temperature rise and maximum ambient temperature at which the choke will

Table 5
Type Tests on Chokes

Test	Acceptance Conditions
Running current at test voltage	To pass $\pm$ 3 per cent. of rated current at the test voltage specified by the manufacturer.
Short-circuit or starting current	Current shall not exceed the maximum value specified for the particular circuit with rated mains voltage applied.
Watts loss	Not to exceed the design figure by more than 10 per cent.
Crest factor	Should not be greater than 1.8 when measured at rated current.
Temperature rise	Acceptance figures according to type of choke (Section 3.1)
Insulation resistance	Shall not be less than 2 megohms measured at 500 V., D.C. between windings and case, with the coil at a temperature of 75 deg. C.
High voltage	Shall withstand a sinusoidal voltage of 1,000 RMS maintained between terminals and case for one minute.
Winding insulation	Shall withstand a voltage of twice rating at 100 cycles for one minute.
Compound leakage test	No leakage shall occur when the choke is held in a position most conducive to leakage with top rated mains voltage applied. Test made at an ambient temperature of 60 deg. C. in free air for a period of 8 hours.

safely operate continuously. This temperature grading would give users a range of control gear from which chokes could be selected suitable for particular designs of fitting or operating locations. Further, it is considered that all chokes should be designed so that they can withstand fault conditions in the circuit continuously.

Suggested test methods and pass limits, where applicable, are shown in Table 5. The supply may be taken from a continuously variable transformer which should be of ample rating to avoid current waveform distortion. All tests should be made at 50 cycles frequency. If a supply of precisely 50 cycles is not available, reasonably accurate results may be obtained by adjusting the test voltage in direct proportion to the deviation in frequency. In the measurement of crest-factor, small errors in the observation of peak voltage can invalidate the result.

Both crest factor and watts loss are related to the size and shape of the choke. Elongating the shape tends to increase losses and crest-factor. Reduction in size and cost have the same effect. It is considered that, as a general principle, loss in a choke should not exceed 25 per cent. of the appropriate lamp rating.

Chokes should also be tested for noise, preferably by aural comparison in a quiet room against a calibrated choke. Tests are made with a suitable lamp in circuit and both choke and lamp should reach stable operating conditions before testing. The lamp is included in these tests as its electrical characteristics affect the waveform of the current and therefore the character of the noise produced by the choke. A very small percentage of lamps, which are otherwise normal, may cause the associated choke to be abnormally noisy. Lamps themselves may also emit sound. Such lamps should be avoided for this test.

The aural method of testing is preferred as elaborate precautions are required to ensure reliable results from objective noise tests. The level of noise permitted may depend upon the ambient noise level of the situation in which the choke is to be used.

(3.2) Capacitor

The principal electrical characteristics of a capacitor are capacitance and the working voltage for which it is suited. For power factor improvement, the capacitance must be at least sufficient to provide the minimum power factor specified under any operating conditions, between the limits of $\pm$ 6 per cent. of the rated voltage of the control gear. In the interests of economy in manufacture, tolerances on capacitance

Table 6
Type Tests on Capacitors

Test	Acceptance Conditions
Capacitance (parallel capacitors)	To be not less than the specified value when measured at working voltage and frequency.
Capacitance (series capacitors)	To be within $\pm$ 5 per cent. of specified value when measured at working voltage and frequency.
Over-voltage	Shall withstand twice working voltage at 50 cycles maintained between terminals for one minute. Note.—Capacitors subjected to this test should not subsequently be put into service.
High voltage	Shall withstand a sinusoidal voltage of 1,000 RMS maintained between the terminals (joined together) and container for one minute.

should be kept as wide as possible, and it is sometimes convenient to specify the minimum value and to have the "plus" limit open. For series capacitors, however, the capacitance must provide correct lamp operating conditions with a tolerance of ± 5 per cent. or better.

Capacitors used for power factor improvement should be suitable for continuous operation at the supply voltage and frequency, whilst series capacitors must be suitable for 440 volt working.

Capacitors are limited to certain working temperatures, which are determined by the behaviour of the insulating materials when operating with alternating current. If these temperatures are exceeded the expected lives of capacitors are reduced very rapidly. For example, an increase in operating temperature from 40 deg. C. to 60 deg. C. may easily halve the life.

In practice, by suitable layout of control gear, it is not difficult to ensure that the operating temperatures of capacitors are kept below the limits stated by makers. With ballasts, where choke and capacitor are housed together in one container, however, the temperature needs careful control if the limits are not to be exceeded.

Test methods and pass limits, where applicable, are shown in Table 6.

(3.3) Starting Device

The two main types of starting device are starter switches and starting transformers.

(3.3.1) *Starter Switches*

The function of a starter switch is first to short circuit the lamp so that current passes only through the cathodes for a time sufficient to raise them to emission temperature, and then to open, causing a pulse of energy to be injected into the lamp.

For each size of lamp a critical amount of energy is required and there is a critical pulse voltage, below which striking will not occur. In general, the lower the cathode temperature when the pulse is injected the greater the pulse required. Among other things this means that a very short preheat time increases the necessary pulse voltage. The R.F. suppression capacitor lengthens the pulse and plays an important part in striking the lamp.

(*i*) *Thermal Switch*

Specifications should cover pre-heat time, no-blink current, and re-set time.

It is not necessary to specify pulse voltage as modern thermal switches provide voltages well above those required for striking the lamp.

It is also of little importance to specify heater watts since it is no advantage to use heaters of more than two watts, and almost impossible to make effective switches with heaters of less than one watt. Thus limits already exist. The pre-heat time, no-blink current and re-set time are not variable independently, but are controlled by the initial contact pressure of the switch. A reduction in contact pressure decreases the pre-heat time and no-blink current but increases the re-set time, and vice versa. It is desirable for the no-blink current to be as near as possible to the minimum current at which the lamp will stay alight, for the re-set time to be as short as possible, and for the pre-heat time to be approximately one second. As these requirements are mutually contradictory a compromise is necessary.

The following limits are practicable for 80-watt lamps:—

(a) Pre-heat time ..... 1-3 seconds;

(b) Re-set time ..... 15 seconds;

(c) No-blink current 60 per cent. of nominal lamp current

The lower the nominal lamp current the more difficult does design become, and some concessions on (b) and (c) are necessary.

It is immaterial whether tests are made with a fluorescent lamp in the circuit. It can be used as an indicator, but other methods are just as good.

It is important that tests are carried out at the maximum mains voltage, at which voltage a glow may be established in the switch. This may cause an alteration in characteristics, and particularly in the re-set time which may be increased from ten seconds to two minutes. The re-set time should be taken after the switch has been running at nominal lamp running current for long enough to reach a stable temperature, i.e., for at least 20 seconds. Life tests may be made by rapid repetition of the starting cycle. In such tests the off period should be at least 20 seconds to allow the thermal switch to re-set.

(*ii*) *Glow Switch*

Specifications should cover striking time and no-blink or extinction voltage.

The obvious method of testing glow switches is to set up the appropriate lamp circuit and carry out striking time, extinction and life tests, but precautions are necessary to obtain reliable results.

For striking time tests a leading circuit should be used. The mains voltage should be set at 90 per cent. of the lowest voltage of the range and there should be no conductor near the lamp. For type tests, at least, the lamps used should be new and cold. A leading circuit is specified as it is possible to design switches which will not close at all on leading curcuits at 180 volts (200 volts minus 10 per cent.), although satisfactory on lagging circuits at the same voltage. The striking time should not exceed 10 seconds.

The extinction test should be made at 130 volts for 200/250 volts range and 65 volts for 100/125 volts range. This will ensure that switches will not operate after the lamp has struck. The test voltage should be applied by lowering the voltage immediately after the switch has closed, without switching off.

The life test should include two separate tests—(a) under normal circuit conditions the starting cycle is repeated rapidly and striking time and extinction tests are made at every thousand strikes up to 8,000; (b) tests are made under circuit fault conditions with a lamp which will not strike owing to deactivated cathodes. The circuit is left switched on for 20 hours during which time the switch attempts unsuccessfully to strike the lamp. After this period the glow switch is retested for striking time and extinction.

It should be noted that other test methods which exclude the lamp are in use but there seems little likelihood of agreeing requirements which will ensure satisfactory operation.

(3.3.2) *Starting Transformers*

Starting transformers may be divided into four main categories:—

(i) Those providing constant cathode heating, suitable for direct connection to the supply, i.e., mains energised.
(ii) Those intended for operation across the lamp—not suitable for series capacitor circuits.
(iii) Those intended for operation in conjunction with series capacitors.
(iv) Current-operated types.

Their function is to raise the lamp cathodes to emission temperature so that with an adjacent earth and suitable atmospheric humidity conditions the lamp will strike at normal supply voltages. Transformers listed in (ii), (iii) and (iv), above, are used in circuits which provide for the supplementary cathode heating to be reduced when the lamp has struck.

When considering performance limits, it should be noted that starting transformers

are usually designed to specific requirements and to operate under certain conditions. When the transformer is used in a circuit providing a high voltage pulse or a step-up of mains voltage, the cathode heating may be less than that required for circuits starting the lamp at normal mains voltage. The effect of low cathode heating on lamp life has already been discussed earlier in the paper.

Whilst it would be possible to specify a number of tests by which the electrical performance of the starting transformer could be judged, these tests alone might not ensure satisfactory performance with any lamp under all the conditions affecting lamp striking. Type tests on starting transformers for satisfactory starting of the lamp should be made with numbers of lamps of various makes under all possible conditions of use, also taking into account supply voltage variations. Casual tests with one or two lamps may give entirely misleading results.

Other tests, which may be made without a lamp in circuit, are:—

(a) On load test—load equivalent to the condition after the lamp has struck.
(b) Temperature rise—fault conditions such as would prevail if the lamp failed to strike.
(c) Insulation resistance. (See Table 5.)
(d) High voltage test—500 volts A.C. applied between windings intended to be isolated from each other. (See also Table 5.)
(e) Winding insulation. (See Table 5.)

(4) Specification and Testing of Fitting

The construction of fittings may include metal work for body or chassis, translucent material for lamp enclosure, protective finish, lamp holders, starter switch holders, terminal blocks, fittings wire, insulating sleeves, adhesive insulating tapes, grommets, screws, nuts, washers, and chain link or tube for suspension.

The fittings should provide satisfactory operating conditions for lamp and control gear, be safe mechanically and electrically, ensure ease of installation and servicing, and utilise and redirect the light from the lamp.

For a complete specification all the items mentioned above would have to be referred either to British Standard Specifications, I.E.E. Regulations, I.E.S. Code or, where no such guidance is available, to requirements ascertained after test. For the purpose of this paper it is intended to consider only those items on which guidance is not as yet available.

(4.1) Design of Lamp Enclosure and Chassis

The volume of lamp enclosures, and the location and method of mounting control gear in the fittings, should be such that the limiting temperatures for lamp and control gear are not exceeded.

For the fluorescent lamp, approximately 80 per cent. of its running watts appear

Table 7
Relation between Lamp Enclosure Volume and Temperature Rise

Lamp dimensions (Length × diameter)	Lamp watts	Max. temperature of lamp operating range. (Fig. 2)	Max. recommended wall temperature	Volume of lamp enclosure. Lamp volume multiplied by
		deg. C.	deg. C.	
5 ft. × 1½ in.	80	49	59	9
4 ft. × 1½ in.	40	40	50	7
2 ft. × 1½ in.	40	52	55	15
3 ft. × 1 in.	30	45	55	8
2 ft. × 1½ in.	20	37	47	7

as heat. More watts are dissipated in the lamp enclosure than in the control gear enclosure.

A number of tests have been made to obtain an empirical guide to the relation between enclosure volume and temperature rise, for different lamp sizes. A totally enclosed luminaire was used, with control gear mounted centrally over an acrylic lamp enclosure. Lamps were run at nominal watts. The tests showed it to be unlikely that the maximum recommended operating temperature of the glass wall of the lamp, at top centre of its length, will be exceeded if the volume of the lamp enclosure is not less than that shown in Table 7.

Where an adjacent earthed surface is necessary, provision should be made for this in the design of the chassis. In the authors' opinion, wherever possible this surface should not be more than $\frac{1}{4}$ in. from the glass wall of the lamp.

The layout of control gear and method of mounting on the chassis should provide for adequate heat dissipation. The capacitor should be mounted in the coolest position, i.e., away from chokes and the lamp cathode area. As far as possible control gear should be mounted on a surface which is free to the atmosphere, since metal partitions between lamp enclosure and control gear quickly absorb the heat from the lamp. There should be good overall contact between the control gear container and its mounting surface.

Mounting the choke in an enclosure usually amplifies any choke noise. This amplification can be minimised by effective mounting, e.g., avoiding loose fixing or fixing to a surface which may act as a diaphragm.

The design of reflector should satisfy accepted values of optical cut-off, and where a translucent enclosure is used the luminance and luminance gradation should conform to modern recommendations.

(4.2) Protective Finish for Metals

Fittings generally utilise one or more of the following metals—mild steel, aluminium and brass, and it is important to adequately protect these metals against corrosion. Various processes are available for the protective treatment of metals, including vitreous enamelling, electrolytic finishing, and synthetic stove enamelling. Protective finishes for reflecting surfaces should retain their colour and reflectivity.

The vitreous enamelling process[10] requires an enamelling quality of steel and is at present not in general use for aluminium. To ensure satisfactory coverage of the metal by vitreous enamelling it is necessary to impose certain limitations on the shape of components.

For aluminium surfaces the anodising process is available, and nuts, screws, and other small fitments can be protected by cadmium, nickel and zinc plating processes. These processes should satisfy the relevant British Standard Specifications[11].

Synthetic stove enamelling processes may be used for steel, aluminium or brass, taking the usual precautions for cleaning and pretreating each metal. As a result of field tests over a number of years it is the authors' opinion that it is possible to provide a stove enamelling process which will withstand most service conditions likely to be encountered by a lighting fitting.

Service conditions should be stated in specifications for fittings, as the type of protective finish to be provided may be varied to satisfy different conditions. For the purpose of specification and test the authors have found that service conditions may be divided into three categories—Normal, Class A and Class B, as detailed in Table 8.

(4.3) Diffusing Materials

For diffusing fittings, some optical properties of the diffusing material can be specified by reference to B.S. 324/1934. The introduction of new diffusing materials,

Table 8
Service Conditions

Category	Conditions
Normal	No special considerations.
Class A	Considerable variations in ambient temperature, exposure to continuous high atmospheric humidity with the possibility of intermittent condensation, exposure to marine atmospheres for long periods, the deposition of dust and grime capable of removal by normal cleaning methods without damage to the enamel finish, low acid content atmosphere.
Class B	As for Class A, and in addition exposure to acid and alkaline vapours and to chemical attack; conditions met in locations where the possible liberation of acid and alkaline vapours and chemical fumes forms a part of the normal working routine.

however, has made this specification inadequate, and its early revision and extension would greatly assist designers and users.

(5) Testing of the Luminaire

Following the specification of each separate component it is necessary to determine the performance of the complete luminaire. Thermal and electrical tests include assessment of temperature rise under normal and fault conditions, lamp striking volts, lamp and control gear watts loss, circuit power factor and high voltage test. Photometric measurements provide data for polar curves, equilux diagrams, etc. Mechanical tests include ease of installation and servicing, vibration and noise tests. The tests to be described are those which form part of the authors' normal procedure for type tests on luminaires.

(5.1) Thermal Tests

In the thermal test, the luminaire is suspended in a draught-free enclosure in its normal operating position, and thermocouples are fixed to points where the temperature rise figures are required. A variable mains supply is connected to the highest voltage tapping of the choke range and is adjusted to plus 6 per cent. of that voltage. The luminaire is run-in for 20 hours during which period (a) temperature readings are taken at hourly intervals on a calibrated galvanometer, (b) the temperature rise in the choke winding is measured by the increase of D.C. resistance method, and (c) lamp and control gear watts losses are measured. In addition a lamp restriking test is made under these operating conditions by switching off for 20 seconds and switching on again.

A similar series of tests is made under fault conditions. Readings as (a), (b) and (c) above are taken, and on removal of the fault the lamp should strike immediately. This test for lamp striking is made at regular intervals. The circuit is maintained under fault conditions for a period of three weeks or longer if required, to determine whether the control gear will withstand onerous fault conditions continuously without an electrical or mechanical breakdown.

Readings obtained in both tests indicate the temperature build-up on the various

surfaces, the most suitable positions for mounting control gear, and whether the lamp and control gear enclosures require further ventilation. The fitting may be "temperature graded," indicating by how much the lamp wall free air operating temperatures are raised by mounting the lamp in the fitting.

(5.2) Electrical Tests

Tests for lamp striking volts with transformer start circuits are made to ascertain whether the luminaire provides conditions suitable for striking the lamp, i.e., adequate adjacent earthed surface where this is necessary. Details are given in Section (2.2). Readings are taken on a group of not less than 12 new lamps with at least 12 strikes per lamp. The above tests are repeated after a run-up period of eight hours.

When making wattage measurements on circuits incorporating fluorescent lamps, compensation is made for meter consumption since corrections which are negligible for normal circuits are often important at the relatively low currents and wattages of fluorescent lamps.

For starter switch circuits, total watts and lamp watts are measured by the usual method; control gear watts loss is obtained by deducting lamp watts from total watts.

For transformer start circuits, total watts are measured as above, and lamp watts by a photometric substitution method. For this, the lamp is run-up for at least 20 minutes to obtain stable operating conditions and a reading is then taken of the light output from a given area of the lamp surface, the photometer being fixed in a housing which fits snugly over the glass wall. The same lamp is then operated in a switch-start circuit, using the choke portion of the transformer start ballast, and the voltage is adjusted to obtain the same light output from the same portion of the lamp bulb surface. Wattage readings are then taken in the normal way.

(5.3) Photometric Tests

Specifications usually call for data to be provided in the form of polar curves, equilux diagrams at varying mounting heights, coefficients of utilisation and luminaire light output ratio.

Tests are made on a polar co-ordinate photometer. The luminaire is mounted in its normal operating position during measurement. If the luminaire is suspended in any other position variations caused by temperature changes may occur. The distance between the photocell and the light source is 25 ft.(9). Lamps of known lumen output are used and run at rated watts. As the luminaire is in its normal operating position, readings for equilux diagrams in two planes can be taken on the same machine.

All readings are taken in an enclosure whose interior surface is painted matt black; the readings are corrected to the published average lumen output figures for the lamps used.

Polar curves in vertical planes provide information of the upward and downward lighting and cut-off. Coefficients of utilisation and light output ratio are calculated from these curves.

(5.4) General and Mechanical Tests

The luminaire is tested for ease of installation and servicing under onerous conditions, the accepted principle being that installation and servicing should be possible by one person. For servicing there should be easy access to control gear. Lamp replacement should be possible with the minimum movement of the ladder. Reflecting surfaces should be free from projections, giving a "one sweep" cleaning action where possible. Alternatively, reflectors should be easily detachable for cleaning at floor level.

For the vibration test the luminaire is mounted on a platform which can be rocked and subjected to impact for varying periods and frequencies. Weaknesses are noted.

Noise tests are made by aural check in a quiet room. The grading of chokes from the point of view of noise could be based on tests described in Section (3.1).

(6) Recommendations

Consideration of the whole subject leads the authors to suggest that specifications and published data should be based on the following recommendations:—

(i) Average lumen output figures for fluorescent lamps should be those of bare lamps operating at nominal watts in free air at 20 deg. C. It is suggested that the corresponding lamp wall operating temperatures at top centre of the lamps be also stated.

(ii) Fittings manufacturers should state by what amount the lamp enclosures of their fittings will raise the lamp temperatures.

(iii) Control gear should be "temperature graded." The maximum permissible temperature of the air surrounding the control gear and the maximum temperature of the outside of the choke container should be stated.

(iv) Lamp colours should be standardised and the standards reviewed at regular intervals. Colours should be specified and named or coded. This name or code should not be applied to any lamp whose colour does not comply with the specification.

(v) The term "Luminaire" should be used to denote the complete lighting unit (Section 5).

References

(1) Thayer, R. N., and Hinman, D. D., Ill. Eng., **40,** 640 (1945).
McFarland, R. H., Ill. Eng., **46,** (1951).
(2) Vorlander, F. J., and Raddin, E. H., Ill. Eng., **45,** 21 (1950)
(3) Lowry, E. F., National Tech. Conf. Ill. Eng. Soc., 1950.
(4) Baumgartner, G. R., Ill. Eng., **36,** 1340 (1941).
Winch, G. T., Trans. Illum. Eng. Soc. (Lond.), **11,** 107 (1946).
Little, W. F., and Salter, E. H., Ill. Eng., **42,** 217 (1947).
(5) Wright, W. D., "The Measurement of Colour," (Hilger 1941).
Buck, G. D., and Thayer, R. N., Ill. Eng., **42,** 415 (1947).
(6) Bouma, P. J., Philips Tech. Rev., 2.1, 57 (1937).
Winch, G. T., and Ruff, H. R., Trans. Illum. Eng. Soc. (Lond.), **16,** 13 (1951).
Judd, D. B., and Jerome, C. E., National Tech. Conf. Ill. Eng. Soc., 1950.
(7) C.I.E. Proc. (1951).
(8) Judd, D. B., and Jerome, C. E., loc. cit.
(9) Baumgartner, G. R., loc. cit.
(10) B.S. 1344 : 1947.
(11) B.S. 1615 : 1949; B.S. 1706 : 1951; B.S. 1224 : 1945.

Discussion

MR. S. ANDERSON: I admire the courage of the authors for tackling so large and complex a subject in a single paper. Naturally, in the confines of the paper they have only been able to touch on certain aspects; others have had to be omitted through lack of space and of time, but I think they have covered far more than we can digest or even attempt to discuss in the time available.

I feel that the paper has come in some respects at a very opportune time, because with the spread of the use of fluorescent lighting, the problems which have been referred to are assuming ever increasing importance and it is obviously of value that they should be set down and put before the widest possible interested audience. It is evident from the paper that to obtain a successful result the co-operation of the designer, the lighting engineer, and the user is needed. We cannot say when we have trouble with a lighting installation that the trouble is necessarily the fault of the designer, the lighting engineer or the user; often all three are involved and the sooner all three can get together and understand each other's problems and points of view, the better will be the results obtained.

In another way it is perhaps a little inopportune that this paper should come at

this time because, as many of you may know, there are in a fairly advanced state of preparation draft British Standard Specifications covering fluorescent lamps, control gear and fluorescent fittings. I think many of us will shortly be receiving draft copies of these for comment, and perhaps it might have been advantageous if the various people responsible for the drafting of these specifications had had the data given in this paper during the earlier stages of preparation rather than at this late stage. Now all they can do is to await the comments. At the same time I feel that we have had a most interesting paper and I am sure there will be many points in it to which later speakers will want to refer.

One point I would like to make is that with any sort of specification to which a manufacturer may try to work, he must obviously study the user's point of view. I am sure there must be a great many users here to-night, and I hope we shall have the opportunity of hearing their views expressed. In any specification for general use I feel that it should be made quite clear that it is a specification of minimum requirements. It seems to me that we shall be doing a disservice to lighting progress if we lay down a specification which limits both maximum and minimum requirements. We must always allow room for improvement while rightly precluding any tendency in a downward direction.

One of the points with which the authors have dealt at length is the question of temperature. It is obviously a very important one, and it looms large in all problems concerned with the use of fluorescent lighting, but there is one aspect which I feel has not perhaps been given sufficient attention in the suggestions for the various temperature limits. This is the one basic temperature which is quite out of the control of the designer, the manufacturer and usually the lighting engineer too—the ambient temperature in which the fitting may have to work. I think perhaps the authors will suggest that the way out of this difficulty is to use the grading system they have mentioned, although I regard that as being more concerned with the choice of suitable gear to go in a particular lighting fitting. My own feeling is that sufficient is known about the range of ambient temperatures which one normally meets in these latitudes, and in other latitudes for which the equipment is destined, to fix acceptable temperature rises. While it may be a good thing to try to differentiate between temperate and tropical service, I do feel that the matter is being over-complicated if we are to sub-divide temperature circumstances in our own latitude and take into account relatively small temperature variations. It seems to me that in this country, where we are already inflicted with such a variety of supply voltages requiring different ratings of control gear, to multiply this by different ratings for a variety of ambient temperature conditions would add to our troubles and to the cost of the equipment.

Whilst the effect of the variation in lamp wall and surrounding temperature on efficiency is well known, I think that it is going too far to suggest that one should design a fitting in such a way that at a given ambient temperature the lamp is developing light at the temperature for maximum efficiency. I think the curve relating efficiency to lamp wall temperature is sensibly flat over quite a range of temperatures, and I hope the authors will confirm my impression that we can allow some latitude without a serious sacrifice in efficiency.

One last point on efficiency in connection with control gear losses. The authors have suggested a figure of 25 per cent. of the lamp wattage. I feel we are being a little illogical if we accept a figure as high as that for gear losses, when at the same time we are considering losses of perhaps 1 or 2 per cent. in efficiency due to changes in temperature. A loss of 25 per cent., particularly with the 4-ft. 40-watt and 5-ft. 80-watt lamps, is rather high, and I personally would like to see a lower figure proposed. With the smaller lamps the situation is different, and the gear designer may

well find it difficult to improve on a 25 per cent. loss. Do not the authors think that a lower figure could be aimed at for the 80-watt lamp?

MR. A. B. READ: It has been very interesting to hear this paper about the complex matters which must be thought of if fluorescent lighting fittings are to be well designed and to satisfy the user.

There is little point in going back over the rather sad history of the premature marketing of fluorescent fittings—sad because they were sold before the public were aware of the way these fittings worked. We have progresesd, but, in the course of our business, we have been surprised to learn how ignorant the normal user still is of the working of fluorescent fittings.

From the designer's point of view the many problems to be considered appear a little overwhelming, but I have always found it is no great disadvantage to know nothing of the technical side, provided I can obtain and use information from those who do know; we have had tremendous help on the technical side from manufacturers of equipment and lamps.

The word " observer " is used in the paper. This, I imagine, refers to people with normal vision, but I wondered whether there might possibly be some research of a more intangible kind. For example, lighting is to a great extent bound up with sentiment. The really important decisions in life are seldom made on a basis of pure reasoning, and prejudice against fluorescent lighting—and prejudice there certainly is—might be removed if one could ascertain what this prejudice really is. The qualities of light create emotional reactions of varying kinds in different users, and if one were able to analyse these one might get some clue to the best uses of fluorescent lighting.

This paper impressed me very much, and there was so much in it that I began to wonder whether I would ever again dare to design a fluorescent fitting. However, I now realise that with the right technical guidance I can carry on with complete confidence.

MR. F. WIDNALL: I would like to comment on the section of the paper dealing with choke specification and in particular temperature rise specifications.

The problem is a difficult one and I do not know on what basis the authors have determined the different figures given for surface temperatures, but I would say that the limiting feature is the temperature that the insulation will withstand, and the normal way of defining this is to define the maximum winding temperature rise.

In the normal types of materials used for chokes I know of no particular reason for varying the acceptable temperature rise, in other words, what applies to one design of choke should equally apply to another.

The user would I think have great difficulty in selecting chokes for particular applications from an assortment claiming different temperature limitations.

I think that we need to know more of the different types of insulation proposed and the differences in design involved on which the authors' proposals are based.

MR. C. R. BICKNELL: We have in this paper the counterpart of the old problem as to which came first—the chicken or the egg. The authors tell us that a single " ideal " lamp is impracticable, so they select a group of good lamps to cover the characteristics of an ideal lamp. They then go on to say that having such a group of lamps a " standard " choke can be made. What gear do they use to select the lamps since the control gear is not made at that stage?

Later on they talk about a " reference " choke which, they say, " . . . may be defined as a production choke whose performance lies at the middle of the appropriate specification." Surely, anything that lies in the middle of a specification lies at a point of no tolerance and is, therefore, in all essence a " standard "?

Referring to photometry they say that " with care good results can be obtained

using a rectangular box." The method discussed is purely substitutional and consequently one would expect a rectangular box to be satisfactory, but I would like to know what special, as distinct from common-sense, care has to be taken, if any.

I agree with the authors that the defining of the colour of fluorescent lamp emission by colour temperature is unsatisfactory. It is a practice that is more common in other countries than here, and we should discourage it.

Finally, I would have liked to have seen a few more references in the paper to the work done in this country. Many references are given to American matter, but much work has been done in this country also.

MR. J. CATES: Water repellant coatings on the glass tubes are very effective at high humidities, but my experience is that they are not effective at temperatures near freezing, and I would like to know the authors' opinion in regard to this.

My second point is to do with the starting of lamps with filament heating transformers, in particular the so-called pulse-start type of circuit, which has recently appeared on the market. In this particular type of circuit the voltage across the lamp at starting is of such a value that the lamp will tend to cold start even without the pulse, with a detrimental effect on life; the pulse has a certain effect, but it is, I think, really a subsidiary effect.

The authors state that the temperature for an unfilled type of choke may be very much higher than in a compound-filled choke, but I question that statement. My own experience is that with compound-filled chokes the permissible maximum temperature depends on the melting point of the compound and in practice it is feasible to use a compound which will enable the choke to operate safely at temperatures similar to those permissible for the unfilled type of choke.

The paper states that a rise of temperature from 40 deg. C. to 60 deg. C. can halve the life of the capacitor. I think this seems an overstatement since the capacitors are normally expected to operate at temperatures of the order of 50-60 deg. C. It should be remembered, too, that these capacitors may also have to withstand tropical conditions, where the ambient temperatures may be 40-50 deg. C. and the operating temperature on the capacitor is correspondingly higher.

One final point as regards the statement on the starting of lamps with a starter switch, where the authors say that the suppressor increases the duration of the pulse. Although the suppressor may increase the duration of the pulse it reduces the pulse voltage and may make starting more difficult when the maximum peak voltage is of importance. The suppressor also tends to increase the pre-heating time of glow starters by sticking action on the contacts.

MR. H. R. RUFF: While fully supporting the principle that in the design and specification of fluorescent lamp circuit components each component should be specified exclusive to the lamp, it should be realised that this method has been in general use since the introduction of electric discharge lamps around 1932. In the fluorescent lamp circuit we have the starter switch added, and if this is of the glow-starter type it appears at present that tests using lamps are so much simpler than the specification of the glow discharge characteristics that the use of lamps is still generally preferred.

There are a large number of points concerning lamps in the paper, and it has been interesting to compare some of the authors' slides with diagrams in a paper read jointly to the I.E.E. and this society in 1942*.

Much of the data appears to be in close agreement. For instance, the slide showing variation of fluorescent lamp efficiency with temperature seemed similar to that in Fig. 17 of the earlier paper, and I would like to know whether the authors'

* Davies, L. J., Ruff, H. R., and Scott, W. J. J.I.E.E., **89**, Part II, 447 (1942).

data refers to lamps with internal coatings of silicate or halophosphate phosphors. Our earlier curve referred to the former, but the mean data from batches of lamps show that the efficiency with the latter types is materially improved at the higher operating temperatures, a useful point when special conditions do not permit the lamps running under their optimum conditions.

It is mentioned that the variation of life with the frequency of switching varies considerably between different makes of lamps. There is probably much more difference between lamps of the same manufacture in different types of circuit. The reduction in life to 50 per cent. with the reduction of the running period from three hours to one hour is much greater than given in Fig. 2 of a previous paper on transport lighting†. This emphasises the point that for specification purposes It would be preferable to life-test one type of circuit—I would suggest the switch type of circuit.

There are many difficulties in connection with life-test specifications on long-life lamps. Forced life tests can be extremely useful for development, but we agree that their general application may be erroneous. It may be possible to specify a shorter running period than that required to get the true average-throughout-life value and still get a reasonable degree of accuracy. Our tests indicate that the off-period could be reduced to a satisfactory minimum of one quarter of an hour, and it would be helpful to people fitting up timing devices if the total running and off-period could be three hours, a proper fraction of a day.

Much of this work has already been covered by the appropriate B.S.I. committees, and I think the specification of the fluorescent lamp has but one major problem remaining—the question of lamp-colour specification. In the paper the authors mention the pioneer work from this country in specifying both colour appearance and colour rendering. While, as they mention, the specification bands for the latter are not finally established, I believe that a very big move forward was made in trying to get international standards of colour, when this country's suggestion that our bands be used to collect data from all countries was accepted by the C.I.E.

MR. J. B. HARRIS : I think the paper has succeeded in demonstrating to consumers that the production of fittings does necessitate technical study and that their design and manufacture call for more knowledge than that possessed by the average sheet metal worker. Unfortunately there are many consumers who, lacking technical knowledge, still think of fittings in terms of shades, and that is why I am pleased to see that there is the hope of a specification being produced.

Under the heading of General and Mechanical Tests, I do not wholly agree with the principle stated that the installation and servicing of fittings should be possible by one person. Although this may apply to domestic units, the vast majority of commercial and industrial fittings which are used to-day are of such a shape and size as to require the services of two men, and from the safety angle I think this should be encouraged.

There seems to be no mention made, in Section 4, of lampholders. The authors do refer to the fact that existing specifications refer to other components but I think that lampholders are very important, bearing in mind, of course, that the majority used to-day are of the bi-pin type. I think there should be some specification in view of the enormous variety that are in existence to-day.

Regarding photometric testing, I think it would be very helpful if consumers were able to obtain more general information appertaining to the different fittings in existence. Such data as Co-efficients of Utilisation, etc., should be presented in a standard form as is done in America, where it is very easy to compare the characteristics of different fittings on an agreed uniform basis.

Bearing in mind the question of replacements and spares and the general

† Ruff, H. R., Hull, J. N., and Mills, R. V., Trans. Illum. Eng. Soc. (London), **14**, 57 (1949).

standardisation of fittings designs by large consumers, I am wondering whether the authors would think it a good thing to have a definite clause covering the dimensions of control gear ballasts. I do not know whether this is possible but it would be extremely useful to be able to keep a minimum stock of replacement items and it does facilitate matters to have only one size of choke, etc., for one rating of lamp.

MR. D. C. PRITCHARD: In testing fluorescent circuits, to obtain minimum starting voltages, is it inadvisable to control the input voltage with a 2-kw. variable transformer, or will the induced voltages in the circuit be unaffected? In the paper, reference is made to corrections for variations in the frequency of the supply volts but the limits to which one can apply the correction of varying the voltage inversely to the frequency is not stated. Is it possible for 40-cycle control gear to be tested on 50-cycle supply, by merely correcting input voltage correspondingly?

Reference is also made in the paper to the selection of lamps for deducing lumen efficiency figures. It is stated that although lamps with a high lumen output are included, those with low lumen output are rejected as being harmful to the final average results. Is this a sound principle to be applied to the computing of average lamp performance, or does it give a high result which, although commercially advantageous, is not technically correct?

MR. J. B. COLLINS: Is the effect of temperature on efficiency due to the effect on the fluorescent powder or on the vapour pressure of the mercury?

MR. W. S. RAWSON-BOTTOM (*communicated*): I would express my appreciation to the authors for a very interesting and purposeful paper. It does bring into prominence the lack of specification relating to fluorescent lighting equipment; but if any had been produced in the past they would have been outdated before obtaining general acceptance.

Much of the information given in the paper is not so well known as might be expected, so that it should provide a useful reference for those concerned with these problems. For example, the influence the design of the lamp enclosure and ballast unit has on lamp performance is often neglected.

There is a definite need for a specification on ballast units. Whilst I am aware of the development work still proceeding and also that it might be considered premature, an interim specification might be opportune. This applies more particularly with quick start ballasts where there is a wide variation in performance in practice.

Is the popularity of the starter switch method on the wane? If so, should not any work on a specification be concentrated on the quick start method?

The authors suggest temperature grading of ballast units. It may be a good suggestion in some respects, but would manufacturers want to add to the already long list of ratings available?

If the units are designed to withstand fault conditions continously, would this not tend to increase size and weight beyond economical limits?

There is a need for a simple but reliable autocut to protect equipment when a fault occurs which a normal fuse does not always do.

The section dealing with specification of fittings is very informative but there is much more that could have been said, especially in regard to mechanical construction. A promising design can be ruined with poor mechanical features. A comprehensive specification should also take into account the internal wiring, ease of assembly and fixing, and there is as yet no specification for bi-pin lampholders.

I hope this excellent paper receives the recognition it merits.

The authors reply to the discussion as follows:—

Mr. Anderson makes a good point in his reference to the fact that the ambient

temperature in which the luminaire may have to work is outside the control of the designer, manufacturer and lighting engineer. It is because of this that we have found the temperature grading of equipment so very useful. For control gear, data is provided stating (a) the maximum permissible temperature on the outside of the container, together with (b) a figure for the maximum temperature of the air surrounding the gear whether it be mounted in a metal enclosure or not. If the gear is to be mounted in a fitting enclosure, then the designer of the fitting should provide sufficient ventilation to ensure that this limiting value is not exceeded. After further test the fittings designer can state the limit of atmospheric temperature which, with the ventilation he has provided, will ensure that the value for (b) is not exceeded. Similarly, if the gear is mounted free to atmosphere, then the limit of ambient temperature is set by this value. This system of grading does concern itself with the choice of suitable gear to go into a particular fitting after considering the ventilation provided by the fitting and the atmosphere ambient temperature in which it is required to work satisfactorily. Far from being complicated, the scheme has assisted associated manufacturers and customers, both home and overseas, to select fittings and the correct control gear to be housed inside them.

In our opinion the effect of lamp wall temperature on efficiency is not sufficiently well known outside the lamp industry to fittings designers and users. Our intention was to stress that if a fitting with very little ventilation for the lamp enclosure is used at high ambient temperatures, then a sensible drop in lumen ouput will result. A higher lumen output will result if the ventilation is increased, or if an open fitting is used. This information enables the designer or the user to select the most satisfactory size and wattage of lamp and the best design of fitting to suit the location.

We cannot agree that the curve in Fig. 2, which is based on results of our own tests, is sensibly flat, and for guidance of users we have made the recommendations in Table 7 giving limits of lamp wall temperatures for the various sizes of lamps.

Regarding control gear losses, the suggestion that loss in a choke should not exceed 25 per cent. of the appropriate lamp rating was proposed more from a consideration of the heat liberated within the fitting than from the power wasted. We appreciate the need for low losses.

In reply to Mr. Rawson-Bottom, although the future of the starter switch is a matter of conjecture, in view of its advantage over the transformer starter under conditions of high temperature or humidity it is likely to remain in use for many years.

We feel that grading of ballast units into the three temperature ranges should not in itself require any increase in the number of types available. Units designed to withstand fault conditions continuously are made with materials which are satisfactory under those conditions. We do not foresee a tendency to increasing size and weight by providing this feature.

We agree that there is a need for a specification not only of bi-pin holders but also of starter switch holders and starter switches.

Mr. Bicknell seems to have misunderstood the purpose of the paper, which is primarily concerned with specifications and not with hypothetical points of historical interest. There are two good reasons for starting with the lamp: (a) the lamp provides the light and conditions must therefore be made suitable for the lamp to give its best performance; (b) lamp watts and dimensions are fixed and can hardly be altered to suit the control gear. Any production choke can be used for the elimination of "outsiders" which is all that is required in the group used as the "ideal lamp."

Care is necessary in using a rectangular box photometer to ensure that differences between test lamps and standards in spectral distribution, temperature at time of measurement, and end-to-end variation in brightness, are eliminated. The paper does not refer to the use of colour temperature for defining the colour appearance of fluorescent lamps, a practice which is convenient for colours on the black body locus.

Mr. Bicknell appears to have misread the reference to the use of black bodies in colour rendering as standards for lamps "well off the black body locus."

Mr. Cates refers to water repellant coatings. These are effective in avoiding the rise in striking voltage due to the deposition of moisture on the lamp wall, but they do not counteract the rise in striking voltage due to low temperature; the two effects are quite separate.

Any form of "cold-starting" causes a reduction in lamp life, and the pulse-start type is no exception. Lamp life is, however, on the increase and it may well be that some sacrifice in life is justifiable if advantages in starting are obtained.

Mr. Cates' statements concerning the effect of the suppressor capacitor are theoretically correct, but in practice with argon filled lamps the reduction in peak voltage is more than offset by the increase in pulse duration, so that starting is assisted by the presence of the suppressor. The effect on contact sticking depends on glow switch design and condenser value.

In regard to compound filled chokes we would refer to the specification for a well-known type of filling compound which gives a heat resistance of 77 deg. C and requires to be poured at 175 deg. C. These two values can only be brought closer together by making the compound much more expensive. Any increase in the present pouring temperature would lead to trouble with soldered joints and possible damage to insulating materials.

We find that manufacturers of capacitors are generally reluctant to quote figures for the ultimate life of a capacitor on A.C., particularly if high operating temperatures are involved, and we took advice before making any statement on the subject.

In reply to Mr. Ruff we agree that some of the data presented and methods suggested are not new to some people, but they are not sufficiently widely known and used in practice.

The curve showing the variation of efficiency with lamp wall temperature was obtained with many different types of phosphor. We do not agree that there is much difference between different phosphors over the range of temperature considered, the effect being almost entirely due to variation in mercury vapour pressure. This question was also raised by Mr. Collins.

The choice of starter for life test purposes is dealt with in the paper. Mr. Ruff is correct in suggesting that a shorter running period than that required to get the "average efficiency through life" should give reasonable accuracy in this respect, but unfortunately this provides no safeguard on duration of life, for which tests must be taken at least to half the declared life. The life test off-period can be reduced to ¼ hour but the suggestion to use a total three-hour period, i.e., 2¾ hours on—¼ hour off, is unacceptable owing to the inconvenience of calculating the total running time. With this cycle it is impossible to arrange the 100-hour period in normal working hours.

Mr. Ruff draws attention to the fact that it has been the accepted practice to test auxiliaries apart from lamps. However, we still find it necessary to advise users to do this and have accordingly emphasised it in the paper.

In reply to Mr. Pritchard we have found that the 2 kva variable voltage transformer is quite satisfactory for controlling the supply for choke testing. In suggesting a correction for frequency variation, however, we only intended to allow for what have come to be regarded as normal variations in the 50-cycle supply. It would not be advisable to use 50 cycles for making type tests on 40- or 60-cycle ballasts.

The reference to "limitation of spread within the batch . . . by limiting the low efficiency lamps, since variation upwards is not harmful" does not mean harmful to the results as Mr. Pritchard infers but *to the customer*. We are suggesting a direct limitation (for acceptance purposes) of low efficiency lamps, rather than the method

applicable to incandescent lamps, namely, the specification of coefficient of variation, which does not discriminate between high and low lamps.

In answer to Mr. Harris we agree that lampholders are important and that there should be a specification to cover them.

Data concerning coefficients of utilisation are available for luminaires in a form which permits comparison of the characteristics of the fitting.

It would, as Mr. Harris suggests, be desirable to have standard dimensions and fixing centres for chokes. An approach to this was attempted by some manufacturers a few years ago and is being reviewed at regular intervals. It may be premature even yet to take steps which might cramp development.

Mr. Widnall suggested that the user would find great difficulty in selecting chokes for particular applications. There are three possible categories into which chokes might be graded: (a) chokes which many users insist on housing in the same container as the capacitor; (b) chokes which could not be combined with a capacitor but still might be compound filled, and (c) varnish impregnated chokes.

Tests on varnish impregnated windings are still in progress. We do not know yet the maximum temperature at which they can be operated, or what their life will be under those conditions. The indications are, however, that the temperature will be considerably higher than the present limit for compound-filled chokes.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

CORPORATE MEMBERS:—

Cooke, T. S. ..... 4, Belfort Road, Gateacre, LIVERPOOL.
Jury, D. H. H. ..... 93, Ashmore Grove, Welling, KENT.
Kumar, B. ..... c/o Basant Pran and Co., 9, Old Court House Street, Calcutta, INDIA.
McLeod, D. ..... 341, Easter Road, EDINBURGH.
Metha, S. F. ..... Sleater House, No. 1, Sleater Road, Grant Road, Bombay, 7, INDIA.
Murthy, B. K. N. ..... 21, B.I.T. Three Room Block, Matunga Road, Bombay, 19, INDIA.
Price, S. E. ..... 25, Oakfield Grove, Clifton, BRISTOL, 8.

TRANSFERRED TO CORPORATE MEMBERSHIP:—

Powell, C. R. F. ..... Exterior Lighting Dept., General Electric Co., Ltd., Magnet House, Kingsway, LONDON, W.C.2.

Fellowship

The Council has accepted the following applications for Fellowship of the Society:—

Dr. W. J. Wellwood Ferguson.
Mr. J. F. Stanley.

The Annual General Meeting

The annual general meeting of the Illuminating Engineering Society was held at the Winter Garden, Eastbourne, at 2.30 p.m. on Thursday, May 22, during the course of the Society's Summer Meeting. The President, Mr. J. G. Holmes, was in the chair. The Secretary having read the notice and the statement of the auditors for the past year, it was agreed that the minutes of the last meeting be taken as read and were approved.

Report and Accounts for 1951

The President then presented the Report of the Council for 1951. (See *Transactions,* Vol. XVII, No. 4, 1952). The President referred to the continued satisfactory growth in membership and in particular to the increase in the number of student members, which Council hoped members would continue to foster. He also reported on the formation of the North Lancashire Group. He said that a prize competition in memory of J. S. Dow had been initiated, the competition being intended to encourage collaboration between students of architecture and engineering. The President referred to the first Trotter-Paterson Memorial Lecture, which had been given by Dr. J. W. T. Walsh in January, 1951, and said that the second memorial lecture would be given by Prof. E. D. Adrian, O.M., President of the Royal Society, early in 1953. The President concluded by thanking the officers and vice-presidents of the Society and those who had served on committees in London and in the Centres and Groups for their work during the year.

The adoption of the Report was proposed by Mr. H. Hewitt, of the Manchester Centre, who said that the Society continued to make very satisfactory progress and thanked the officers and members of Council for their administration of the affairs of the Society during the year under review.

The proposal was seconded by Mr. N. Slater, of the Nottingham Centre. In the course of his remarks he asked for better attendance by Centres representatives at Council meetings and urged Centres to increase their efforts to organise courses in illuminating engineering. Referring to finance he paid tribute to the work of the hon. treasurer, Mr. W. J. Jones, and also to the honorary treasurers of Centres.

Mr. Howard Long also commented on attendances at Council meetings and to the need for safeguarding the value of the Society's financial reserves.

The resolution on the adoption of the Report was then put to the meeting and was declared carried unanimously. The President, on behalf of the officers and Council, thanked the meeting for their expression of thanks.

Election of Officers and Council.

The President reported that there had been no independent nominations for officers for the 1952-53 session and the following were therefore declared elected:—

President:—Dr. W. J. Wellwood Ferguson.

Vice-Presidents:—Mr. A. G. Higgins, Mr. E. C. Lennox, Mr. A. H. Owen, Mr. J. F. Stanley, Mr. W. J. P. Watson.

Hon. Treasurer:—Mr. W. J. Jones.

Hon. Secretary:—Mr. H. C. Weston.

Hon. Editor of the Transactions:—Dr. W. E. Harper.

Following the announcement of the names of Council's nominations to fill vacancies on the Council from October 1,

1952, an independent nomination had been made and a postal ballot held with the result that the following were elected:—Mr. A. D. S. Atkinson, Mr. F. M. Hale, Dr. R. G. Hopkinson, Mr. R. A. Lovell, Mr. J. S. McCulloch, Mr. W. T. F. Souter, Mr. W. R. Stevens, Mr. D. L. Tabraham.

This concluded the formal business of the meeting.

Printed by
ARGUS PRESS, LTD.,
Temple-avenue and
Tudor-street,
London, E.C.4,
England.